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Evaluation of performance-aware internal vertical sealing systems: a case study comparing two types of walls using life cycle assessment for the same acoustic performance

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Abstract: *The construction industry is one of the most important and, at the same time, the most striking Brazil sectors. The evaluation of this industry impacts can aid in decision making throughout the project process. Brazilian Building Performance Standard, NBR 15575, combines the challenge of designing low-impact buildings with the performance requirements for all building systems. In this context of a search for reducing impacts, an approach that compares constructive systems of the same performance is needed to verify valid alternatives concerning Brazilian standards. With this, the main contribution of this paper is. With this, the main contribution of this paper is to verify the best option between the internal vertical sealing systems through LCA considering the same acoustic performance. The LCA results of internal vertical sealing systems revealed critical points such as the significant difference of impact of a ceramic brick system to a drywall system of the same functional unit when one considers the same acoustic performance. With the standardized results for the drywall system, it was possible to identify how much the ceramic brick system is more impacting than the drywall system when acoustic performance is considered with this systems' specific configuration. However, the results have limitations when using adapted data. They don't represent the reality of a national industry exactly. Besides that, Brazilians data are an industry average, and a specific industry's impacts can be different. The impact category that had the most significant difference in systems impact was climate change, where the impacts of the ceramic brick system are three times higher than the drywall system. Also, the ceramic brick system is the main contributor to the impacts because of the large quantities needed to meet the defined acoustic performance. However, this study's results consider one configuration of each system, besides using some simplifications for its development.*

Key words: *environmental impacts, acoustic performance, LCA, drywall, ceramic brick.*

INTRODUCTION

The construction industry represents one of the most important and impactful economic activities nowadays, moving around 6.2% of the Brazilian GDP (IBGE, 2017), representing 34% of the Brazilian industry (IBGE, 2017). The construction sector is one of those that most demands energy and natural resources, generating several environmental impacts. The sector also transforms the natural and the built environment, responsible for approximately 50% of the consumption of natural resources and 40% of energy inputs from all sources worldwide (Tavares, 2006).

The global climate is changing rapidly, and this phenomenon will continue over time. Studies indicate that human activity has a 95% influence on global warming (IPCC, 2014). Besides, buildings are responsible for a large part of environmental impacts throughout their entire life cycle. Therefore, the decision making in the choice of construction systems has great importance in environmental impacts. Through changes in the way buildings are designed, constructed, and managed, there is a reduction of impacts.

The need for sustainable buildings is a recurring theme at the international level. Standards were created to improve the environmental performance of products, including buildings (ISO 14040,2006; ISO 14044,2006; ISO 15686,2008; ISO 14031,2013; ASTM E214-19,2019). Some standards also combine users' safety and welfare with low environmental impacts to promote buildings sustainability (ABNT 14040; 200 CSIC, 2019). The construction sector needs to adopt innovative approaches to introduce new concepts and procedures to achieve more sustainable construction and meet performance standards. The quest for sustainability in the construction sector is the way for the construction industry to move towards sustainable development, taking into account social, economic, and environmental issues.

LCA, standardized by ISO 14040 series and widely documented, is considered a method for evaluating environmental impacts. This evaluation tool is systematic and analytical to measure sustainability, which is now indispensable in facing environmental performance and compatibility between economic growth and sustainability. Such demands have made LCA an increasingly used tool in civil construction.

Some studies that consider acoustic performance and LCA (ASDRUBALI, 2016; RICCIARDI, 2014) evaluate a constructive system's thermal and acoustic behavior, then perform LCA and compare the results with other different systems. While other studies compare the thermal performance of building systems or their advantages and disadvantages, they use LCA to measure environmental impacts (KIM, 2011; CONDEIXA, 2015; OTTELÉ, 2011). However, none of the studies compare different systems' acoustic performance using a set value of performance.

In this context of seeking to reduce the impacts of civil construction, an approach is necessary that compares constructive systems of the same performance, to verify valid alternatives.

The tiles and ceramic brick represent 90% of the bricks and roofs built in Brazil (ANICER, 2019). Also, the ceramic brick system is composed primarily of mortar and ceramic brick, and the cement and ceramic brick, together with rebar, PVC pipe, sawn and plywood, account for more than 90% of the incorporated energy and emissions of greenhouse gases incorporated in materials (FRANCO, 2013).

A prefabricated system with increasing market representativeness chosen to carry out the comparison. The use of drywall in Brazilian civil construction has maintained an increasing rhythm. The annual consumption of drywall sheets in Brazil was 39 million m² in 2011 (ASSOCIAÇÃO BRASILEIRA DE DRYWALL, 2013). Drywall consumption grew by 12.6% and 13.7% in recent years, confirming the expansion trend.

This article assesses the life cycle of two internal sealing systems: ceramic brick, and drywall, considering that both systems must meet the same minimum acoustic performance stipulated in standard NBR 15575. To the best of the author's knowledge, the scientific literature still lacks LCA studies considering the performance of these constructive systems in the Brazilian context.

METHOD

This study is base on Life Cycle Assessment (LCA) technique, following the criteria of ISO 14040 (2006) and ISO 14044 (2006). This study's goal and scope were defined, including the identification of the functional unit and the specification of the system boundaries. Then, the results of the analyses carried out presented: (i) the comparative LCA of the sealing systems types and (ii) the contribution analysis of the materials of each sealing system type to seven impacts categories—finally, recommendations for a better environmental performance of sealing systems drawn.

The present study aims to verify the best option between the internal vertical sealing systems through LCA considering the same acoustic performance: drywall system and ceramic brick system. The study provides a better understanding of these systems' possible environmental impacts regarding the minimum acoustic performance established at local standards. This study also aims to collaborate with the construction sector in obtaining data on the impact that design decisions can reflect on the total environmental impact of the buildings' life cycle.

LCA Goal and Scope

This LCA aims to compare the potential environmental impacts of two internal vertical sealing systems with the same acoustic performance. The functional unit is as 1.00m² of a residential building's drywall system and ceramic brick system for 50 years. This unit is independent of the constructed building area and can serve as an indicator of the life cycle's potential environmental impacts.

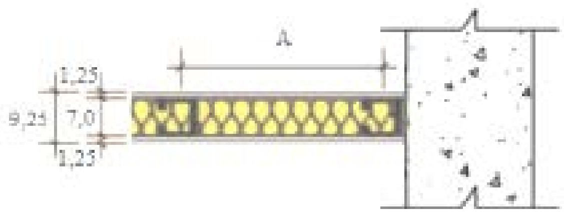
Both systems were chosen to meet the same acoustic performance requirements. The acoustic performance allows the verification of the acoustic insulation provided by the seal, between the external and internal environment, between autonomous units and between unit dependence and common areas (ABNT 15575, 2013). Each system must individually have 45 dB performance, established in most scenarios presented in NBR 15575. In this sense, the chosen construction systems, ceramic brick, and drywall have the same function, internal vertical sealing with a minimum acoustic performance of 45 dB.

Drywall is considered a dry construction system, which is used exclusively as an internal vertical seal, whose consumption has recently increased in Brazil, especially in the state of São Paulo (CONDEIXA, 2013).

The primary inputs for constructing the drywall system are profiles, guides, galvanized steel uprights, gypsum boards that can fill with mineral wool, and finally, mass and tape used to seal their joints. Mineral wool, glass wool or rock wool, increase their thermoacoustic efficiency and accommodate the uprights. The system's performance depends on its composition, the number of plates, profiles size, cavity thickness, and presence of insulation.

The composition chosen for this study has as structured an upright profile and a guide profile. The frame is sealed on both sides by standard plasterboard filled with 5 cm thick rock wool felt, totaling 9.5 cm thick, as shown in Figure 1. This system has Rw = 49dB, being higher than the minimum determined as a requirement in this study. Despite being outside the study's scope, this system attends all the performance requirements of NBR 15575: 2013 for an internal vertical sealing system (ASSOCIAÇÃO BRASILEIRA DE DRYWALL, 2013).

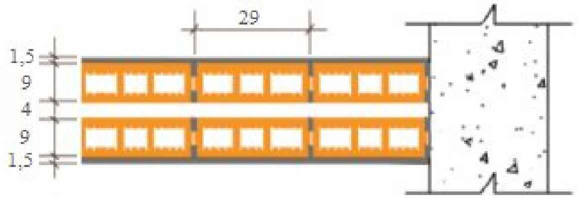
Figure 1. Drywall system 95/70 l. (ASSOCIAÇÃO BRASILEIRA DE DRYWALL, 2013).



In Brazil, the most conventional and predominant construction system is the non-structural ceramic brick system, sealed with coating mortar, usually combined with a reinforced concrete structure, being a system molded on-site (CONDEIXA, 2013). The inputs for this system are ceramic brick, sand, cement, and lime. There are currently Brazil several brick models with different dimensions. Their performances depend on their geometric form, castings, the density of the clay, and the production process (PAULUZZI BLOCOS CERÂMICOS, 2018).

A double-walled ceramic brick system set up to achieve the performance requirements, as shown in Figure 2. This system has a performance of Rw = 49dB (PAULUZZI BLOCOS CERÂMICOS, 2018), being higher than the minimum determined as a requirement in this study and the same performance of the selected Drywall system. Although the double-wall system is not conventional in Brazil, it is chosen to fulfill the acoustic requirements defined for the study.

Figure 2. Ceramic brick system. (PAULUZZI BLOCOS CERÂMICOS, 2018).



Both systems are evaluated considering the same life cycle phases: product stage (A1-A3) and transport of the construction process (A4), considering the same acoustic performance for both construction systems. The use phase (B1-B7) is not evaluated because the systems are not inserted in a context. Demolition, disposal, and recycling are not also assessed since they do not influence the system's performance.

The characterization factors are taken from the compilation of impact categories of the CML 2001, developed by the Institute of Environmental Sciences at the University of Leiden, according to the categories shown in Table 1. OpenLCA v1.9 tool uses to compile the inventory, adapt data to the Brazilian context, and calculate impact assessment.

Table 1. CML impact categories assessed in this study.

Category	Unit
Depletion of abiotic resources - fossil fuels (ADPf)	MJ
Depletion of abiotic resources - elements, ultimate reserves (ADPnf)	kg Sb eq.
Acidification potential (AP)	kg SO_2 eq.
Eutrophication (EP)	kg $(PO_4)^{3-}$ eq.
Climate change (GWP)	kg CO_2 eq.
Ozone layer depletion (ODP)	kg CFC-11 eq.
Photochemical oxidation (POCP)	kg etileno eq.

Life cycle inventory (LCI)

The inventory flows of each system were defined from the listed materials and quantities from SINAPI (2018) and considering the manufacturers' technical specifications.

The state/city of São Paulo is the largest consumer of both technologies (ASSOCIAÇÃO BRASILEIRA DE DRYWALL, 2013). For purposes of determining the distances of transport from the suppliers' factories to the construction site, São Paulo city was selected as the construction site location. To choose the manufacturers, only suppliers registered in the Quality Sector Program - PSQ of the civil construction (CONDEIXA, 2013) were considered, being selected those that are closer to São Paulo. In this sense, we consider that the gypsum plasterboard and the metallic profiles are from Mogi das Cruzes (66 km), stone wool is from Descalvado (245 km), clay brick is from Santo André (30 km), cement and lime are from Santa Helena (115 km), sand is from Jardim Bom Jesus (50 km), and the acrylic paint and stucco are from São Bernardo do Campo (30km).

Background data was extracted from the international database Ecoinvent v3.6 for Brazilian data and the Rest of the World (RoW) data. The criterion for selecting the database's data was considering the system model allocation - cut-off by classification. The data that not founded for the Brazilian reality was adapted by changing the electricity matrix at the first level of the dataset process to a Brazilian matrix.

Table 3 shows the life cycle inventory for the Drywall system.

Table 3. LCI of drywall system.

	Flow	Quantity
Inputs	Stone wool	0.81 kg
	Gypsum plasterboard	17.60 kg
	Reinforcing steel	4.52 kg
	Zinc coating	0.89 m²
	Stucco	0.30 kg
	Transport, lorry 16-32 metric	1.67 t*km
Output	Drywall	1.00 m²

Table 4 shows the life cycle inventory for the Ceramic brick system.

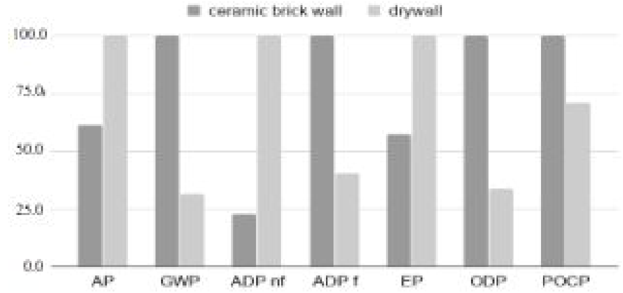
Table 4. LCI of Ceramic brick system.

	Flow	Amount
Inputs	Clay brick production	173.00 kg
	Cement production, Portland	3.94 kg
	Lime production, hydraulic	11.24 kg
	Silica sand production	39.36 kg
	Water	2.76 kg
	Reinforcing steel	0.89 kg
	Zinc coating	0.07 m²
	Transport, lorry 16-32 metric	8.92 t*km
Outputs	Ceramic brick system	1.00 m²

RESULTS AND DISCUSSION

The results show the potential impacts for each impact category for the functional unit defined of 1.00m² of drywall system and ceramic brick system of a residential building for 50 years. Figure 3 presents a comparison between both chosen systems in all impacts categories.

Figure 3: Potential impacts for all impacts categories.



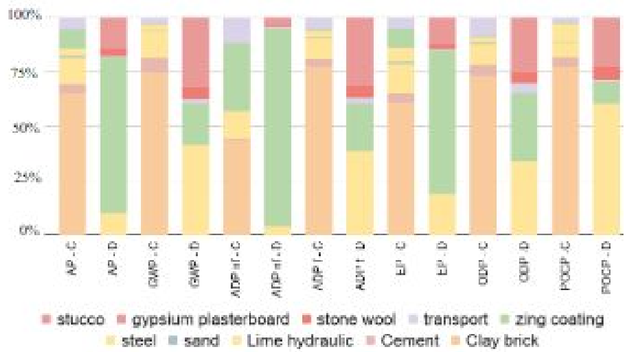
AP: Acidification potential; GWP:Climate change ; ADPnf: Depletion of abiotic resources - elements, ultimate reserves; ADPf: Depletion of abiotic resources - fossil fuels; EP:Eutrophication; ODP:Ozone layer depletion; POCP:Photochemical oxidation.

The ceramic brick system has the most significant potential impact on most impact categories. The drywall system shows the highest potential only in the categories of acidification potential, depletion of abiotic resources - elements, ultimate reserves, and eutrophication.

The most significant difference in potential impacts between the drywall system and the ceramic brick system occurred in the climate change category. The ceramic brick system emits 51 kg CO_2 eq. for 1m² of the wall. We could build with the same climate change impact from the ceramic brick system almost three more walls with drywall systems.

The materials that contributed most to the potential impacts were the ceramic brick in the ceramic brick system and the zinc coating of the profiles and the gypsum plasterboard in the drywall system, as shown in Figure 4.

Figure 4. Contribution systems materials to each impact category, considering drywall system (D) and ceramic brick system (C).



AP: Acidification potential; GWP:Climate change ; ADPnf: Depletion of abiotic resources - elements, ultimate reserves; ADPf: Depletion of abiotic resources - fossil fuels; EP:Eutrophication; ODP:Ozone layer depletion; POCP:Photochemical oxidation.

The ceramic brick impacted a great deal since it was used in high quantity to meet the acoustic performance of the NBR 15575. Transport had little impact on the drywall system because it is a lightweight system. However, on the ceramic brick system, transportation is always more impactful, reaching an acidification potential (AP) five times greater because the ceramic brick system has ten times more weight than the drywall system.

FINAL REMARKS

Comparative LCA of internal vertical sealing systems revealed critical points such as the significant difference of impact of a ceramic brick system to a drywall system of the same functional unit when considering acoustic performance. The ceramic brick system is the main contributor to the impacts since it is used in large quantities to meet the defined acoustic performance. However, the result of this study considers only these configurations of systems, besides using some simplifications for its development, as a configuration of systems that meet the acoustic performance requirements. Besides that, the adapted data do not precisely represent the reality of the national industry. Also, Brazilians data are an industry average, and the impacts of a specific sector may be different.

Building environmental assessments provide essential subsidies for the sustainable development of construction. Also, reporting results to stakeholders and decision-makers help to develop more sustainable alternatives in the construction industry. Future research should also consider the structure of the building in which the system used, as the ceramic brick system is ten times heavier than the gypsum plasterboard. Structure weight is a critical variable for structural projects, thus increasing the impact of the ceramic brick system. Therefore, this study demonstrated that acoustic performance also directly interferes with environmental impacts, showing that the performance approach is very significant in environmental assessments.

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